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Olaf Helmer

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## PROSPECTS OF TECHNOLOGICAL PROGRESS

Olaf Helmer\*

The RAND Corporation, Santa Monica, California

Much has already been said about the prospects of technological progress during the remainder of this century, and I have little to add to these prognostications. I would like to use this opportunity, not primarily to make technological forecasts, but to discuss the role that the forecasting of technological developments plays in shaping the future of our society. In presenting some specific forecasts for the year 2000, I would like merely to provide a certain amount of substantive illustrative material for such a discussion.

The year 2000, with which this conference is concerned, is only one third of a century away from us. But the pace of change in our time, due to scientific and technological advances, is greater than it used to be and is still accelerating. Consequently, the world of 2000 will be far less

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like our present world than our present world is like that of a third of a century ago. Thus a high degree of uncertainty has to attach to many things we may wish to say about the year 2000.

Nevertheless, quite a few statements can be made with some confidence about that world of the future. Let me give a few examples.

It is virtually certain that:

- o The world population will be over 5 billion.
- o The rate of population increase will have begun to decelerate, due to the widespread acceptance of cheap and effective means of fertility control.
- o Absolute food production will be substantially higher than it is today, aided primarily by large-scale desalination of sea water.
- o The world GNP will be more than 3 times and possibly 4 times what it is today, resulting probably in an approximate doubling and possibly in a tripling of per-capita GNP.
- o People will largely live in urban complexes, surrounded by numerous automata. In particular, there will be central data banks and libraries with fully automated access, a credit card economy in which cash transactions will be virtually eliminated, highly sophisticated teaching machines will be in wide use, portable video telephones will facilitate communication

among persons everywhere, and this process will be further enhanced by the availability of automated translation from one language to another.

- o Personality-affecting drugs will be as widely used and accepted as alcoholic beverages are today.
- o The life span of many people will be extended through the common practice of replacing worn or diseased organs by implanting artificial plastic and electronic organs.
- o A permanent colony will exist on the Moon, and men will almost certainly have landed on Mars.

Not quite so certain as the statements just made, but still very probable, are the following:

- o Controlled thermonuclear power will be economically competitive with other sources of power.
- o It will be possible to control the weather regionally to a large extent.
- o Ocean mining on a large scale will be in progress.
- o Artificial life will have been created in the test tube.
- o Immunization against all bacterial and viral diseases will be available.
- o Highly intelligent machines will exist that will act as effective collaborators of scientists and engineers.

Next let me list a few developments that are less

probable but still have a good chance of being part of the world of 2000:

- o Large-scale ocean farming may be practiced.
- o Our highway transportation may be fully automated.
- o Cooperation between man and machine may have progressed to the point of actual symbiosis, in the sense of enabling man to extend his intelligence by direct electromechanical interaction between his brain and a computing machine.
- o We may have learned, through molecular engineering, to control hereditary defects in man, to control the aging process, and to induce the artificial growth of new limbs and organs. We may also have drugs available that raise a person's level of intelligence.
- o In space, we may be mining ores and manufacturing propellents on the Moon, we may have established a permanent Mars base, and we may have landed on Jupiter's moons.

This sample of forecasts, I think, will provide a sufficient substantive background for the following discussion, which will be focussing upon three considerations: (i) the changed role that forecasts play in our thinking about the future of our society, (ii) some of the specific tasks that lie ahead in organizing a systematic analysis of the future, and (iii) the prospects of accomplishing these tasks in the decades before us.

The purpose of long-range forecasts generally is not just to satisfy mankind's persistent curiosity about its future destiny, but the main objective of such forecasts is to inform decision-makers in both the public and private sectors of a nation of potential future dangers that must be avoided and of potential future opportunities that must be seized.

This new, pragmatic, view of the value of forecasting is of relatively recent origin. It reflects a wholly new attitude toward the future among planners and researchers. The fatalistic view of the future as unforeseeable but unique and hence inevitable has been abandoned. We see instead a growing awareness that there is a whole spectrum of possible futures, with varying degrees of probability, and that through proper planning we may exert considerable influence over these probabilities. Although our control over the future, which we might thus aspire to exercise, is merely marginal, we have learned from the economists that small marginal adjustments in planning the domestic affairs of a nation can make all the difference between misery and contentedness for large segments of its people.

This newly acquired realization of our power to affect our own destiny through deliberate long-range planning brings with it a new social responsibility for the scientist and analyst. It falls upon him to provide the kind of comprehensive analysis of the future on which the political process

of influencing the future must rest.

A responsible analysis of the future calls for a program with these three components:

1. A survey of alternatives, that is, a full exploration of potential future developments, together with estimates of their a-priori probabilities; and a description of the major alternatives with regard to the future state of the world in terms of coherent conglomerations of such developments.
2. An analysis of preferences, that is, an explication of the extent to which the pursuit of any particular alternative state would serve the public interest. In this context, "the public interest" may well have to be viewed from several standpoints, namely, as seen by the executive branch of its government, and - in some sense - as seen by the world community. This analysis of differential preferences should in no way prejudge the issues. Rather, by analyzing the moral implications of professed attitudes and the degree to which the probable consequences of contemplated policies would comply with them, it should enhance the rationality of the democratic decision-making process.
3. Constructive policy research: Having aided the process of selecting the more desirable among the possible futures of the world, the final and most demanding step is that of devising the means of attaining

these futures, or at least of raising their probabilities of occurrence as much as possible through appropriate policies and programs.

These then, summed up briefly, are the obvious desiderata: To find out about the possible futures that lie ahead; to single out the more desirable ones among them; and to invent the instrumentalities for their deliberate pursuit.

An organized effort to enhance our capability, as analysts, to deal with these three tasks is prerequisite to putting the process of shaping the future of our society on a more rational foundation. It constitutes the basis for the application of social technology, that is, for the invention of social institutions and the design of social policies that promise to fulfill our reasonable aspirations. And it is on the prospects of socio-technological progress, in this sense, that I want to concentrate in the remainder of this paper.

The prospects of substantial socio-technological progress during the third third of this century, in my opinion, are very high. I base this optimism on four clearly recognizable trends.

One is the ongoing, explosively increasing, effort devoted to scientific research generally. Judging by the trend during the second third of the century and extrapolating very conservatively, the world's scientific manpower in the year 2000 is likely to be at least five times what it

is today. In addition, because of the availability of more sophisticated instruments and, above all, of more powerful computing machines, the productivity of the individual researcher is apt to rise at the very least by a factor of two. Consequently we may expect the total rate of scientific productivity to grow at least tenfold by the end of the century. The increased understanding of the world we live in that is implied by this development is the first reason for my optimism regarding socio-technological progress.

The second reason, already partly implied by the first, is the second computer revolution, which is already well under way. It took just twenty years for the first computer revolution to be completed, from the mid-forties to the mid-sixties, during which time the computer grew up from being a bookkeeping device to becoming a highly versatile data processor and research tool. During that period the size and the cost of electronic computer components have gone down by factors of 100 and 100,000 respectively, and their speed has gone up by a factor of 100,000.

While these trends will continue for some time and, together with long-distance time-sharing arrangements, will account during the next decade for a continued annual doubling of the amount of computer power in the world, the second computer revolution will add a significantly new flavor to this resource of ours. It will consist of the amalgamation of two separate trends, which in combination promise to have

a powerful impact on planning processes generally. They are (1) the relative automation of the computer, in the sense of doing away with many of the cumbersome aspects of computer programming and thereby facilitating direct communication between the individual researcher and the computer; and (II) the invention of numerous highly versatile display devices, coupled directly to the computer, that permit a designer to construct visual and, when necessary, moving images of his ideas as he develops them. These two trends, which are well under way, will constitute the beginning of a true symbiosis between man and machine, where in a very real sense man's intelligence will be enhanced through collaboration with a computer.

My third reason for taking a bright view of future progress is social technology is that there is yet another, subtle revolution in the making, namely a reorientation among social scientists toward policy-related research. Instead of continuing the relatively futile endeavor to emulate the physical sciences, researchers in the social-science area are realizing that the time has come to emulate physical technology. They are beginning to do this by seeking an interdisciplinary systems approach to the solution of socio-political problems. They will accomplish this by transferring the methods of operations research from the area of physical technology to that of social technology.

The potential reward from this evolving reorientation of some of the effort in the social-science area toward social technology, employing operations-analytical techniques, is considerable; it may even equal or exceed in importance that of the achievements credited to the technologies arising out of the physical sciences.

Operations analysis was first brought into being through the exigencies of World War II; it has since continued to develop and become a widely accepted tool, not only in the peacetime management of military affairs, but throughout the operations of commerce and industry.

Among the principal operations research techniques that have proven themselves in these areas and that show great promise of being transferable to that of social technology are the construction of mathematical models, simulation procedures, and a systematic approach to the utilization of intuitive expert judgment. All of these techniques - it is almost needless to say - are greatly aided and continually refined through the availability of the computer, and the second computer revolution which I described may well add another order of magnitude to their potency. In particular, automated access to central data banks, in conjunction with appropriate socioeconomic models, will provide the soft sciences with the same kind of massive data processing and interpreting capability that, in the physical sciences, created the breakthrough which led to the understanding and

management of atomic energy.

One of the results of the greater receptivity of social scientists to mathematical models and to an interdisciplinary systems approach may well be the development of a comprehensive theory of organizations, where by this term I mean the general discipline concerned with human interactions in decision-making situations. Taken in this sense, organization theory is a direct extension of the so-called theory of games, - an extension which it is necessary to achieve before we can deal with social conflict situations that the present theory has been unable to resolve. Any form of social interaction, be it among persons or among business firms or among states, can be viewed as a game we are playing, or rather a continuing series of games, in which in some sense we strive to maximize our individual or corporate or national utilities. The next great breakthrough in the social sciences, comparable in significance to such physical breakthroughs as the creation of artificial life or the control of thermonuclear energy, may well be the construction of a theory of organizations that succeeds in dealing rationally with situations of interpersonal or international conflict. My expectation that this breakthrough will occur is my fourth reason for hope in this general area.

How, specifically, will all these developments lead to improvements in the analysis of the future? How, in de Jouvenel's phrase, will they advance the "art of conjecture"?

I described earlier the three parts of which an analysis of the future has to consist. Let us reexamine them briefly.

The survey of possible futures, with which any analysis of the future must begin, will continue to have to rely primarily on the intuitive judgment of experts. The process of obtaining a consensus among specialists will be enormously improved through the developments which I mentioned. Not only will the expected gigantic increase in scientific knowledge raise the quality of available expertise by an order or magnitude, but the day is not too far off when we can establish a world-wide network of specialists, each equipped with a console tied to one central computer and to electronic data banks, who will be able to interact with one another via the computer network and thus obtain a consensus among themselves through a process of which the present-day Delphi technique is a primitive precursor. Aside from procedural refinements in this technique, one of the major improvements that will have to be introduced is that potential future developments will not be inquired into in isolation but that proper attention will be paid to cross-correlations among such developments. For instance, the occurrence of one development may raise the probability of occurrence of another either because it facilitates the other technologically or because it makes the other socially more desirable. A systematic treatment of such cross-influences will be a necessary ingredient of any future survey of possible futures.

With regard to the analysis of preferences, which is the second component of an analysis of the future, I expect that the general reorientation of the social sciences toward policy-directed systems research will lead to considerable advances in the selection and measurement of social indicators. Organization theory, in particular, if it develops in the direction which I outlined, will permit us to view a nation as an organization of individuals, or the world as an organization of nations, in which the members have partly conflicting goals. We may then be able to attack the problem of the welfare of such communities more rationally by dealing with it within the systematic framework of a theory of organizational preferences.

Finally, there is the third aspect of the art of conjecture, namely the meter of constructive policy research. Here we are in the area of what may be called the systematization of social inventiveness. It is apt to benefit most profoundly from the acceptance of operations-research techniques within the social sciences. Program-budgeting, especially, will come of age, by utilizing the conceptual framework of organizational utilities and preferences that we may expect organization theory to furnish. Comprehensive simulated planning by multidisciplinary groups of experts, aided by electronic computers and display devices as well as by sophisticated mathematical models, will result in alternative developmental scenarios. Judging by past experience, the stimulating effect of interacting within a simulated

environment will be highly conducive to inventiveness and imagination among the participants, and we may well look forward to the emergence of a new breed of modern-day constructive utopians, who will invent not only better futures but the social instrumentalities of attaining them.

In summary then, in view of what may reasonably be expected, the potential progress of social technology that lies within the grasp of the next generation is tremendous. First these new methods will find their application within the societies of the advanced nations. But the pace of events is fast in this century, and before it is over I think there is hope that international relations will not remain unaffected by such progress, so that some of us may live to see the beginning of the era when the ample resources of the world will be equitably distributed among all nations, and war will be obsolescent.